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Towards powerful negative ion beams at the test facility ELISE for the ITER and DEMO NBI system

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The negative ion source test facility ELISE represents an important step in the European R&D roadmap towards the neutral beam injection (NBI) systems at ITER. ELISE provides early experience with operation of large RF-driven negative hydrogen ion sources. Its source area is 1x0.9 m2 and the net extraction area of 0.1 m2, formed by 640 apertures, corresponds to a half-size ITER source. The test facility aims at demonstrating large-scale extraction and acceleration of negative hydrogen ions (H^-, D^-) for pulses of up to 1 h with half the current required on ITER. Additionally, the ratio of co-extracted electrons to ions must be kept below one, which is quite demanding in particular for deuterium operation. Starting with first plasma pulses in March 2013, ELISE has meanwhile demonstrated stable 1 h plasma discharges in hydrogen with repetitive 10 s extraction every 3 min with 9.3 A extracted current and an electron-to-ion ratio of 0.4 at the pressure required by ITER of 0.3 Pa but using only one quarter of the available RF power. At half of the available RF power a stable 400 s plasma discharge was achieved with 18.3 A beam pulses at an electron-to-ion ratio of 0.7. Linear scaling towards full RF power predicts that the target value of the negative ion current can be achieved or even exceeded. Issues in long pulse operation are the caesium dynamics and the stability of the co-extracted electron current. Newly developed magnetic filter field configurations allowed achieving for the first time 1 h pulses in deuterium with an electron-to-ion ratio below one, however only at a quarter of the available RF power. Advanced beam diagnostics such as beam emission spectroscopy and a sophisticated diagnostic calorimeter reveal that the requirement on the uniformity of these large beams (deviations < 10%) can be met.

For a DEMO fusion reactor, the requirements of a heating and current drive system will strongly depend on the DEMO scenario and are presently assessed within EUROfusion WPHCD. As NBI systems based on negative ions are regarded as one candidate, ELISE could serve in a later stage as a test bed for concepts concerning RF efficiency, operation without caesium or with largely reduced caesium consumption, and neutralization by a laser neutralizer in order to improve efficiency and reliability. IPP's present small scale experiments show promising results.

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